ISSN:
Print - 2277 - 0593
Online - 2315 - 7461

Journal of Natural Science, Engineering and Technology

SIMULATION OF THE DYNAMICS OF CASSAVA STEM CUTTINGS ON AN INCLINED WOOD SURFACE

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ABSTRACT

Development of precision machines to handle some of the field activities involved in the cultivation of cassava is a highly welcomed project among young enterprising farmers who are keen in resolving the posterity of their wellbeing as a big time farmer. Mechanization of cassava in the tropics is grossly hampered by lack of extensive knowlegde on the behaviour, physical properties of cassava stems and parameters that have great influence on the handling of the stems during cultivation, hence the limitation of advancing the present semi-automatic planter to fully automated one is still a mirage in the tropics. This paper presents the flow properties of cassava cuttings that can lend it to proper handling in a metering machine. A variable inclined wood surface rig with an ejection outlet was used to study the properties of the stem. Measured cassava stem predictive parameters; diamater, lentgh,weight; angle variation on the rig; response parameters; percentage ejected, percentage sliding through, forces acting on stems were obtained. The results from the study could be used to predict acurately the exact dynamics of a given stem isolated from the bulk of stem cuttings stacked in the metering hopper. Models to predict the flow properties of the stems were obtained; further simulation of the dynamics was embarked upon using MATLAB software. A major transition zone of stem characteristics per pecentage sliding to ejection occurred within the range of angles of 15^0-30^0. This might be a favourable angular zone for isolating the stems from the bulk mass while the effectively isolated stems can be metered appropriately by another mechanism in the process of developing a metering device for cassava stem cuttings.

Keywords: plane, dynamics, stem cuttings, simulation, wood surface

CASSAVA PRODUCTION AND ECONOMIC VALUE

Manual cultivation of cassava, (*Manihot esculenta crantz*) is the predominant method of production in the tropics. Cassava production industries in Nigeria for the past few decades have experienced limited use of farm machinery at the early stage of production. The principal method adopted by most farmers in the tropics is the manual method which is an arduous task, time cunsuming and prone to human failures and dissappointments.The root of this crop serves as a major source of carbohydrate and main staple food for a large proportion of Africans (Young Woon and Halos, 1995; Nweke, 2004). Over 500 million farmers are reported to earn their income from cassava production (Plucknett *et al.,* 2000; Agbor Egbe *et al*.,1995). Cock (1985) reported that an estimate of about 238 kcal *per capita* consumption is derivable as dietary calorie from cassava consumption. The crop also serve as a source of raw material for numerous industrial productions (Gottret *et al*.,1996; Sansavini and Verzoni,1998; Ostertag,1996; Leygue,1993; Dufour *et al*., 1996; Henry et al., 1998; Roper, 1996; FAO, 1999 and Plucknett *et al.,*2000)

The current interest in producing ethanol from cassava thereby serving as alternate source in bio fuel blending for automobiles coupled with the policy of adding at least 10 % of cassava flour to wheat for bread production will lead to high demand and shortage of the crop in the nearest future. These envisaged predicaments will grossly be aggravated if the traditional methods of production is still maintained in Nigeria. It is therefore pertinent to improve on this limited method in order to meet up with the expected rise in demand of cassava in the future.

The potential of exporting cassava in Nigeria and Africa will bring about a huge ready source of income generation for the economy which needs to be exploited. In Nigeria, exportation of cassava and cassava products is almost nil despite the fact that the country is said to be the largest producer in the world (Nweke 2004 and Ajibola *et al*, 2001). The traditional production methods are widely adopted by most peasant and medium producers in Nigeria since the use of the existing semi-automatic planters is still cumbersome and labour intensive thereby increasing the cost of production. This expected additional increase in cost of running the semi-automated system might be the strong reason why the peasant and medium scale producers are yet to embrace the method. Many researchers such as Monteiro (1963), Makanjuola *et al.* (1976), Wahab (1977), Odigboh (1978), Odigboh and Ahmed (1982), Ladeinde *et al.* (1995), Lungkapin *et al. (*2009) and Ian (1985) have worked on various forms of planters. None of these were readily available to Nigerian producers. Developing a new metering device for cassava planter is a crucial step in solving the time-consuming, challenging, and arduous task faced by producers.

A study on the dynamics of cassava stems on an inclined wood surface was conducted as a move in addressing part of the problems highlighted above which is a step towards achieving the continuous metering of cassava stems in the semi-automatic planter, thereby turning the present semi-automated system to a fully automated one while reducing the number of hands required to operate such systems. Automation of planting will lead to improvement on the timely cultivation and increase in production level. In order to fully automate cassava planting, there is the need to develop a stem feed mechanism. The feed mechanism would require the knowledge of flow of the stem. This study is therefore to generate information on the stem flow of cassava which is required in the feed mechanism of an automatic cassava planter.

MATERIALS AND METHODS

Geometrical measurements of cassava stems cuttings procured from nearby farm in Alabata, Abeokuta Nigeria were done. The cassava stem cuttings were indentified as the TME419 species. The stems were cut into the required length of 150 mm using a panel saw. The geometrical measurements were made on four samples of cassava stem cuttings of uniform length of 150 mm. The sizes of the stem cuttings were measured using vernier caliper with an accuracy of ± 0.01 mm. The measurement of nodes height on each of the stem cuttings were also recorded while the weights of the samples were determined using a sensitive electronic balance (Metler, model A240).

Rheological behavior of the stem cuttings were evaluated by conducting experiments to determine its flow property on an inclined surface. This surface was set at the following angles 10^0,13^0,15^0,20^0,30^0 and 45^0 during experimentation. The surface had a fixed opening of 55 mm x 200 mm situated at the lower part of the rig to enable the stems to be ejected before reaching the end point of the plane. This way, the intrinsic flow and ejection characteristics of cassava stems cuttings on the inclined surface can be studied using the rig shown in Figure 1. This opening was chosen based on the result of the initial dimensional analysis of the stems measured earlier. A clearance of 15mm and 50 mm were added to maximum diameter

$$D_{\max obtainable}\ \ 40\,mm + 15\,mm = 55\,mm$$

$$L_{(\text{lenght of cutting}\,s)}\ \ +150\,mm + 50\,mm = 200\,mm$$

This was to allow any of the stems rolling down the plane to have a chance of being ejected if favourable conditions warranting this to occur were met.

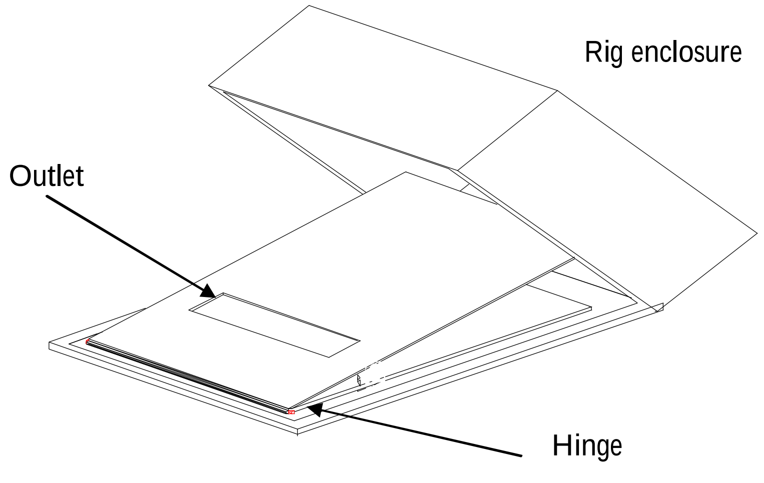

Figure 1: Inclined surface with an ejection outlet

RESULTS

The results obtained for the test conducted on the inclined surface angles of 10^0-45^0 are shown in Table 1:

Table 1: Physical sliding and ejection properties of cassava stem on an inclined plane

Angle		% stems sliding through				% stems ejected			
	Stem diameter	36.5	24.75	24.3	17.88	36.5	24.75	24.3	17.88
100		0	0	0	0	100	100	100	100
130		0	0	0	0	100	100	100	100
150		65	10	5	0	35	90	95	100
200		70	80	10	10	30	20	90	90
300		100	95	60	25	0	5	40	75
450		100	100	100	95	0	0	0	5

The sliding or ejecting characteristic of stem cuttings at six angles of the plane inclination; 10^0 , 13^0 ,15^0 ,20^0,30^0 and 45^0 and various stem weights are plotted in Figures 2,3,4,5,6 and 7 respectively. The plots reveal the behaviour of cassava stem cutttings at the varied angles when the ejection outlet is fixed at 50 mm x 200 mm.

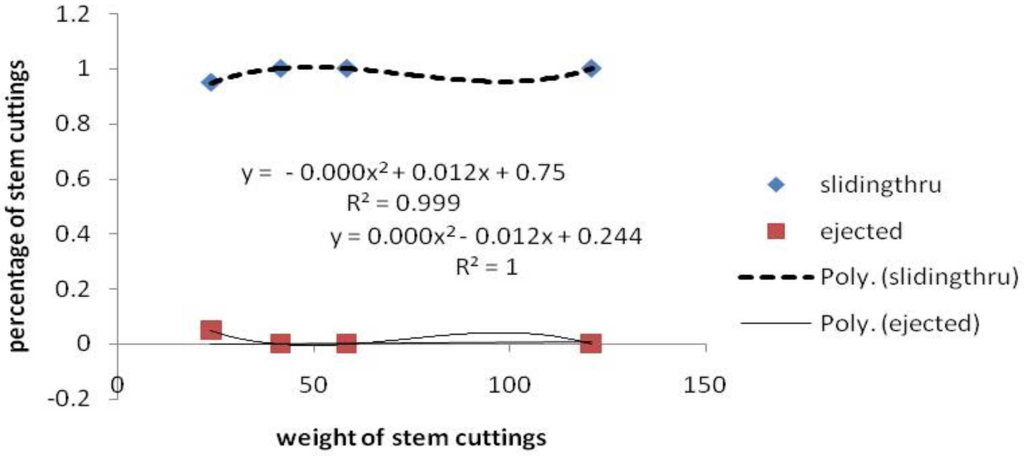

Fig. 2: Flow property of cassava stem cuttings at inclined plane of 45°

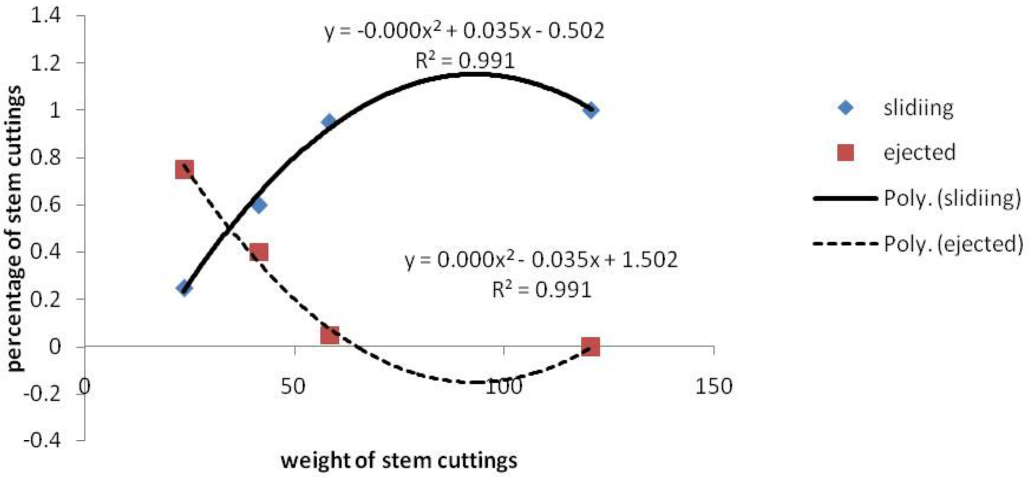

Fig. 3: Flow property of cassava stem cuttings at inclined plane of 30°

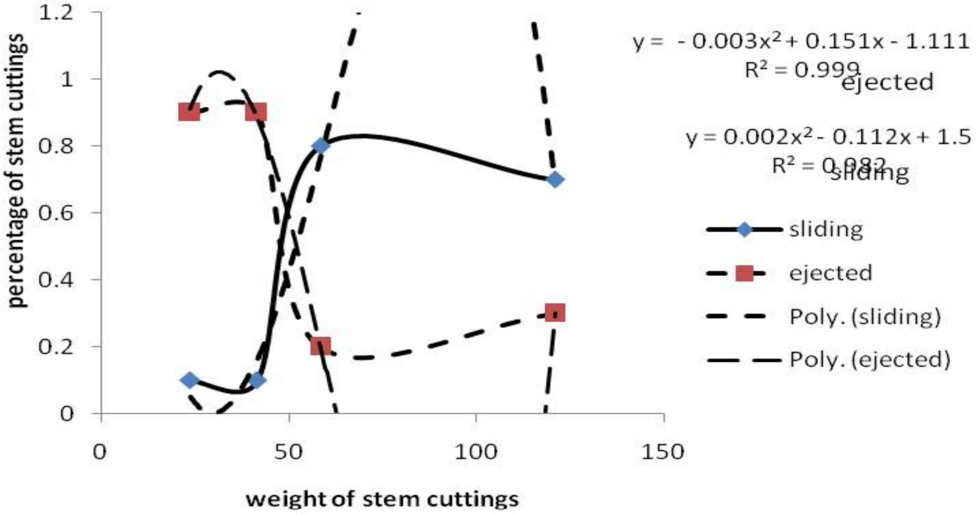

Fig. 4: Flow property of cassava stem cuttings at inclined plane 20°

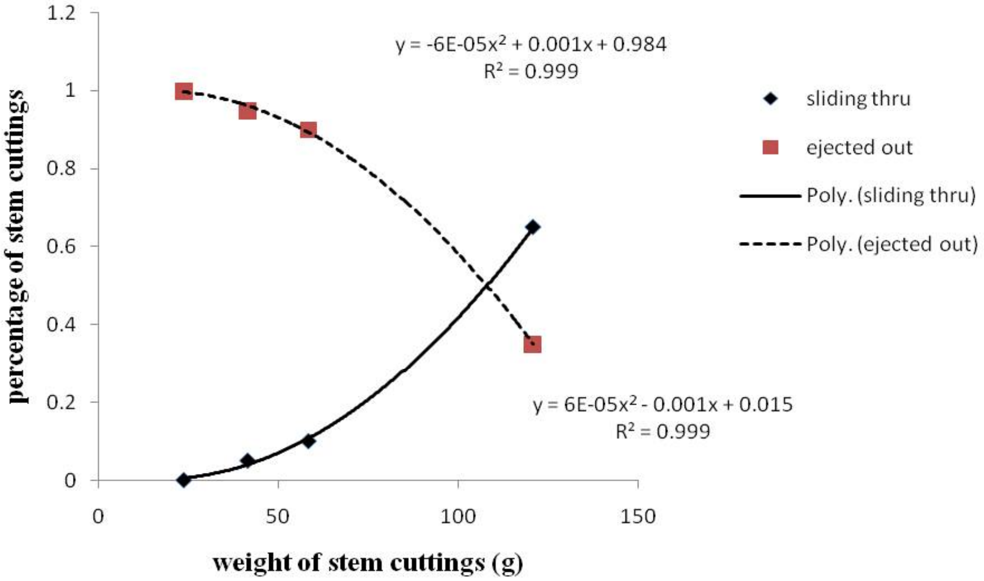

Fig. 5: Flow property of cassava stem cuttings at plane angle of 15^0

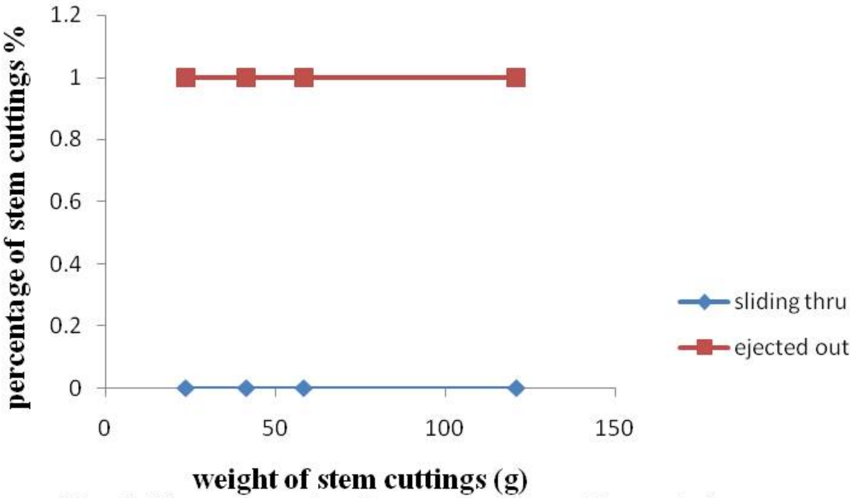

Fig. 6: Flow property of cassava stem cuttings at plane angle of 13^0

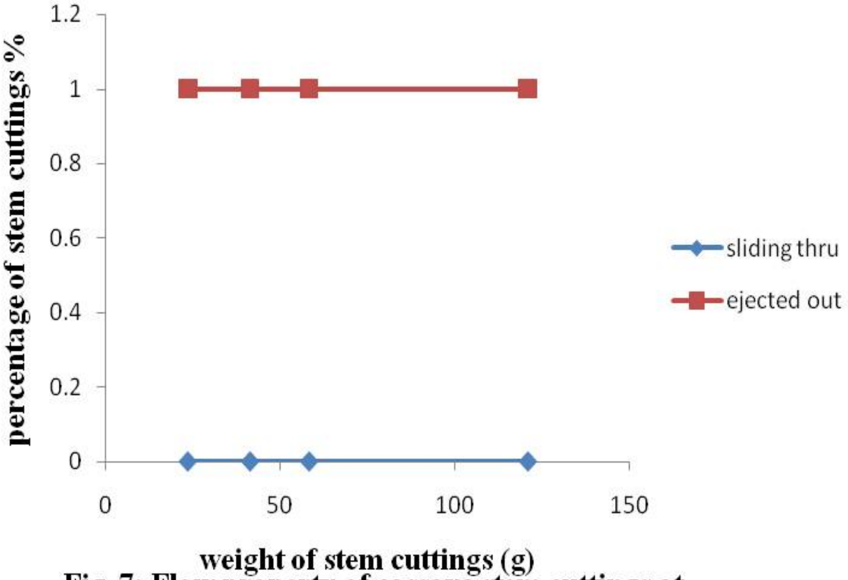

Fig. 7: Flow property of cassava stem cuttings at inclined plane 10°

Analysis

The sliding and ejection properties of a given weight of the stem cuttings as related to the various plane inclinations at fixed ejection outlet of 50 mm x 200 mm shown in Figure 2 - 7. depicts the intrinsic behaviour and charactersitics of the various sizes of cassava stem cuttings being studied. For plane inclination of 45^0, all stems tested on the plane slid through while only 5% were ejected through the outlet provided. It can be infered that all cassava stem cuttings slid down the plane at 45^0 due to effect of the forces acting on the stems along the direction of motion F_x shown in Figure 8. Force F_x ranges from 164.40 N to 838.65 N at constant accelleration of 6 m/s^2. Under this condtion, only 5% of the stems having the weight and diameter of 23.7g and 17.88 mm respectively were ejected while the rest slid through. The forces at play were illustrated in Figure 8. The normal force F_Y that could facilitate the ejection of any of the stems at point E as shown in Figure 8 was equal to F_x hence larger percentage of the stems slid down while only few the stems at the least weight were ejected. The constant accelleration and equal forces acting on the various stems as calculated and shown in Table 2 resulted in more percentage sliding through the plane than being ejected. At angle of 45^0, 95% to 100% of the stems slid through for all the four different sizes stems. The few stems that were ejected at this category might be due to the effect of the stem sizes which allow few chances of 5 % ejection to occur.

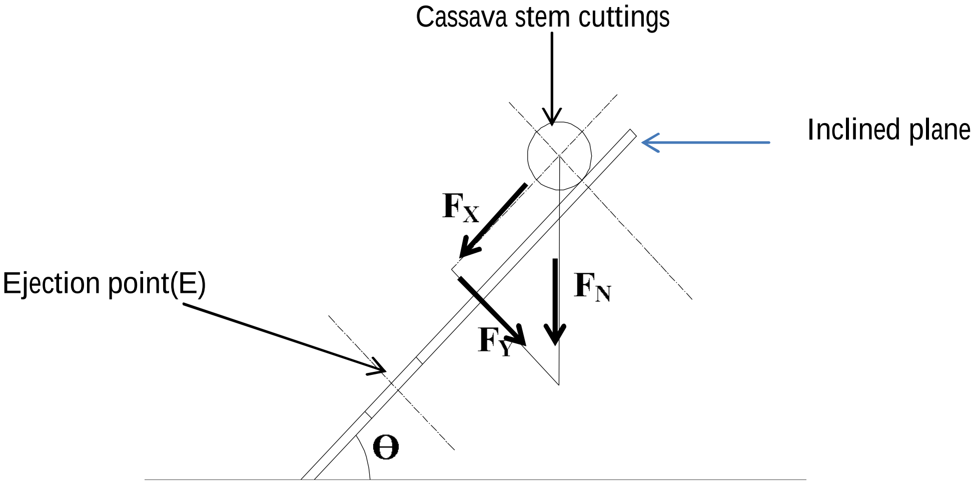

Figure.8: Forces acting on cassava stem cuttings on an inclined

The result of stems sliding at plane angle of 30^0 shown in Figure 3 and this portrays that as the weight of the stem increases more stems were found to slid through the plane while at the least weight more than 75 % of the stems were ejected before reaching the end of the plane. Infact at the largest weight of 36.5 g non were ejected but rather 100 % stems slid through plane.

Table 2: Analyses of forces acting on cassava stemcuttings sliding on inclined plane

Angle	Weight(g)	F_N (N)	F_x(N)	a_x(m/s^2)	F_y(N)	a_y(m/s^2)
45^0	23.7	232.497	164.40021	6	164.40021	6
	41.5	407.115	287.87378	6	287.87378	6
	58.4	572.904	405.1043	6	405.1043	6
	120.9	1186.029	838.64915	6	838.64915	6
30^0	23.7	232.497	116.2485	4	201.34831	8
	41.5	407.115	203.5575	4	352.57193	8
	58.4	572.904	286.452	4	496.14942	8
	120.9	1186.029	593.0145	4	1027.1312	8
20^0	23.7	232.497	79.518657	3	218.47572	9
	41.5	407.115	139.24153	3	382.56296	9
	58.4	572.904	195.94471	3	538.35366	9
	120.9	1186.029	405.64581	3	1114.5027	9
15^0	23.7	232.497	60.174652	2	224.57473	9
	41.5	407.115	105.36912	2	393.24266	9
	58.4	572.904	148.27847	2	553.38245	9
	120.9	1186.029	306.96689	2	1145.6154	9
13^0	23.7	232.497	52.300445	2	227.41638	9
	41.5	407.115	91.580948	2	398.21856	9
	58.4	572.904	128.87536	2	560.38467	9
	120.9	1186.029	266.79847	2	1160.1114	9
10^0	23.7	232.497	40.37268	1	228.96485	9
	41.5	407.115	70.694778	1	400.93001	9
	58.4	572.904	99.483735	1	564.2003	9
	120.9	1186.029	205.95177	1	1168.0106	9

Model development

The model equation obtained that describes the sliding behaviour of the stems at this plane was;

$$y_s = -0.0002x^2 + 0.0355x - 0.5022 \tag{1}$$

with $R^2 = 0.9918$

y_s = the percentage of the stems sliding through and

x = the weight of the the stem

while for the ejection property of the stems on a plane of 30^0 the equation

$$y_e = 0.0002x^2 - 0.0355x + 1.5022 \tag{2}$$

with

$R^2 = 0.9918$ was obtained.

y_e = the percentage stems ejected before reaching the end of the plane.

These two second order equations adequately describe the behaviour of the stems at this plane angle. The value of F_X was reducing while that of F_Y increases simultaneously and progessively as the angle of inclination reduces from 45^0 to 10^0. These relationships of forces acting on the various stem sizes could be seen vividly in the various calculations of forces for each plane inclinations as given in Table 2. The plots of the relationships of forces acting on the stems sliding on an inclined plane with percentage of stems sliding through or being ejected followed a sinuisoidal curve and this is associated with the variations in the inclination of the plane. These variations were related to formula for calculating the tilt angle of the plane and the variations were associated with the varying values of forces calculated for F_X and F_Y in Table 2 observed as the plane inclinations increases. These sinuisodal nature exhibited in all the plots emanates from the two basic equations that were used to determine the two main forces acting on the stems on the inclined plane. These forces are calculated from these two sinuisodal equations which are;

$$F_X = F_N \sin\theta$$

and

$$F_Y = F_N \cos\theta$$

These two equations governs the behavoiur of the stems as it slid or being ejected on the plane since the weight of the stems are associated with F_X and F_Y. thereby resulting to the sinuisodal models obtained in the numerous plots shown.

However when the angle is now at 20^0 the behaviour of the stems was best predicted by a third order polynomial equations that is;

$$y_s = -1E\text{-}05x^3 + 0.0025x^2 - 0.1128x + 1.5$$

$R^2 = 0.9821$

and

$$y_e = 2E\text{-}05x^3 - 0.0032x^2 + 0.1514x - 1.1112$$

$R^2 = 0.999$

The change from second order to third order equation describing the behaviour of the stem cuttings at this plane was as a result of the effect of the accelleration on the stems which had increased to the highest value. This abrupt change observed might be understood from the trend of change giving in Table 2 of the two accellerations acting on the stems. The two model equations to predict the sliding and ejection properties of the stem at plane angle of 20^0 have points outside the data point which could not be plotted due limitation of data (weight in the range of 60 to 110 g were not available) hence a perfect plot at that segement cannot be obtained.

For plane angle of 15^0 more percentages of the stems were ejected at the least weight of 23.7g than those at the largest weight of 120.9 g. As the weight of stem increases the percentage being ejected reduces while the opposite trend occur for the stems sliding through. This behaviour of stems was shown in Figure 5 and the two models obtained at this angle were second order equations which perfectly predict the properties exhibited by the stems with a coefficient of determination ranging between 0.9993 to 0.9993. Transformation of these equations from third order to second order was obtained at 20^0. Again the sharp change in trend from second order equation to third order and back to second order within the angles of 30^0, 20^0 and 15^0 respectively showed that there is transition point linked to the drastic change in accellerations of the stems as they slid on the plane. Observations made at these three angles which had a direct influence on the behavoiur of the stems on the inclined plane show that the critical angles of handling cassava stem cuttings on an inclined plane. The model predicting the sliding characteristics of the stems at plane angle of 15^0 was:

$$y_s = 6E\text{-}05x^2 - 0.0019x + 0.0155 \ldots\ldots (4)$$

$$R^2 = 0.9993$$

while that of the ejection characteristics is

$$y_e = -6E\text{-}05x^2 + 0.0019x + 0.9845 \ldots\ldots (5)$$

$$R^2 = 0.9993$$

Result of plots obtained a little angle less beyond the plane angle of 15^0 showed that all stems were now being ejected (100% ejection) while non could successfully slid down the plane at both 13^0 and 10^0. These results at the two lower angles were due to the maximum downward accellerations a_Y that favour the ejection of the stems.

DISCUSSION

The analysis of the result showed that as the inclination of the rig decreases from 45° to 20° the acceleration component in the normal plane a_y increases from 6 m/s² to 9 m/s². The acceleration reached the maximum value at angle of 20° and it remained constant at this value for angles of 15°, 13° and 10° respectively. This implies that the best angle for ejecting a cassava, under a dynamic flow would be at plane angles ranging from 20° to 10°. The best ejection cassava stems cuttings occurred at angles of 13° and 10°. At these two angles all the stems metered where fully ejected. Setting the angle of discharge to angles of 20°, 15°,13° and 10° would effectively aid the elimination of the cassava stem cuttings in a metering device. Controlled feeding and feed rate of stems is enhanced at these angles and also clogging of stems is prevented due to gradually metering of stems from the hopper. The model obtained could also be used for precise prediction of the dynamics of the stem cuttings on a wood surfave. The exact dynamics of the stem on the wood surface can be determined accurately for point ejection thereby aiding the perfect metering of the stems in a planter.

CONCLUSION

The behavoiur of cassava stems cuttings on an inclined plane are predictable using second and third order equtaions obtained and these are valuable in developing a precision handling machine for harvesting and cultivation of cassava stems cuttings. The transition points observed are essential points of reference in handling cassava stem cuttings for metering unit that could be design for automatic feeding mechanism being proposed for future development. The transition points could be used in designing a suitable metering surface set at an appropriate angle for precision metering of cassava stem cuttings. The models would be useful for precision metering of cassava stems in a controlled dynamic flow metering planter. The models can be used to predict the behaviour stems on wood surfaces.

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(Manuscript received: 1st December, 2014; accepted: 26th June, 2015).